1975

A new method of interfacing pilot to aircraft.

Morge, Kenneth Warren

Monterey, California. Naval Postgraduate School

A NEW METHOD OF INTERFACING PILOT TO AIRCRAFT

Kenneth Warren Morge

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

A NEW METHOD OF INTERFACING PILOT TO AIRCRAFT

by

Kenneth Warren Morge

March 1975

Thesis Advisor George Marmont

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A New Method of Interfacing Pilot to Aircraft		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis March 1975
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Kenneth Warren Morge		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE March 1975
		13. NUMBER OF PAGES 50
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Postgraduate School Monterey, California 93940		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Myoelectric control, Bioengineering, Man-machine interface

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A new method of interfacing pilot to aircraft for control of pitch and roll using myoelectric signals from arm muscles is studied. Electrodes with piggyback amplifiers along with active filters and an active matrixing network are used to process the signals.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
(Page 1) S/N 0102-014-6601 |

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

A New Method of Interfacing Pilot to Aircraft

by

Kenneth Warren Morge
Lieutenant, United States Navy
B.S., North Carolina State University, 1967

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
March 1975

ABSTRACT

A new method of interfacing pilot to aircraft for control of pitch and roll using myoelectric signals from arm muscles is studied. Electrodes with piggyback amplifiers along with active filters and an active matrixing network are used to process the signals.

TABLE OF CONTENTS

I. INTRODUCTION

As increased emphasis is being placed on developing electronic or fly-by-wire control systems for aircraft, and more research is needed in the area of the man-machine interface. Several studies have been conducted (Refs. 2 and 5) to evaluate present aircraft movable control sticks and new designs such as rigid or force sticks to determine which system was best suited for adaptation to a fly-by-wire system.

Studies have been conducted to determine the feasibility of using myoelectric signals as control signals for control of equipment and aircraft (Refs. 2 and 7). The myoelectric system proved to have the fastest reaction time when compared to other man-machine interface systems. The myoelectric system also has importance in delaying or eliminating pilot fatigue, and it requires the least amount of muscular effort. Since very little movement is required, the result is faster and possibly more precise control of the aircraft.

A new electrode configuration is tested as part of a new method of pilot to aircraft interface. The interface utilizes a differential amplifier, a detector-filter circuit, and a matrixing network.

II. BACKGROUND

A. BASIS OF ELECTROMYOGRAPHY

The body muscles used to control an aircraft are complex mechanisms made up of many thousands of muscle fibers. These fibers are connected to the central control center by effectors for transmitting movement signals and by receptors which provide feedback. The effectors are the motor or efferent nerves from the somatic nervous system that end in skeletal muscles and form the motor end-plates.

The receptors are muscle spindles, which detect momentary lengths of muscle fibers and the rate of change of these lengths, and Golgi tendon organs which detect the tension applied to the tendon fibers during muscle contraction. The muscle spindles are small intrafusal muscle fibers which are attached at the ends to the sheaths of the surrounding skeletal muscle fibers and contract only at the ends. The muscle spindle can be stimulated by stretch of the entire muscle by an outside source or by contraction of the intrafusal fibers of the spindle which contracts the two ends of the spindle stretching the middle. The annulospiral receptors in the middle of the spindle and the flower-spray receptors on either side of the middle sense the stretching and transmit signals to the central nervous system.

Contraction of the intrafusal fibers is accomplished by stimulation of the gamma efferent fibers connected to the ends of the muscle spindles and stretches the central

portions if the surrounding skeletal muscle does not contract simultaneously. Taken as a system, this skeletal muscle action serves as a muscular servo-mechanism. This mechanism provides the feedback needed for controlled movement.

A simplified functional block diagram of the nervous system controlling muscle action is shown in figure 1. The sense receptors are the stretch receptors in the muscle spindles and the Golgi tendon organs in the tendons. The reflex response emergency gate is not a major factor in normal receptor/muscle operation. When a reflex response is called for, however, this emergency gate bypasses the signal path to and from the brain and initiates a reflex response. This emergency gate is located in the spinal cord and is triggered by a large signal, that is, a high repetition rate signal being received from a sense receptor. These reflex responses protect the body from serious damage.

All the muscle fibers innervated by a single motor nerve are called a motor unit, which is the biological unit of muscular activity. A motor neuron is a nerve originating in the spinal cord and branching into motor end-plates. The motor end-plates invaginate into the muscle fiber but remain outside the muscle fiber membrane (Figure 2).

Electrical potentials exist across the membrane of every cell in the body. Some cells such as nerve and muscle cells are capable of transmitting electrochemical impulses along their membranes when they are excited. Both of these types of cells are osmotically balanced with potassium ions

on the inside and sodium ions on the outside. Generally, an excess number of negative ions accumulate immediately inside the cell membrane along its inner surface, and an equal number of positive ions accumulate immediately outside the membrane. This results in the development of a membrane potential.

As long as the membrane of the muscle or nerve fiber remains completely undisturbed, the membrane potential remains at approximately minus 85 millivolts, which is known as the resting potential. Any factor that suddenly increases the permeability of the membrane to the sodium ions will usually elicit a sequence of rapid changes in membrane potential lasting a fraction of a millisecond, followed immediately by the return of the membrane potential to its resting value.

This sequence of changes is called an action potential which results in a depolarization of the fiber. This causes current to flow inward through the depolarized portion of the membrane and outward through the portion of the membrane still at the resting potential. The current flow through the resting membrane increases the membrane's permeability to sodium ions which immediately diffuse inward through the membrane setting up a cycle. In the nerve, the action potential propagates from the point of excitation to the neuromuscular junction where another series of events takes place. Following stimulation of the nerve fiber, the action potential either travels over the entire

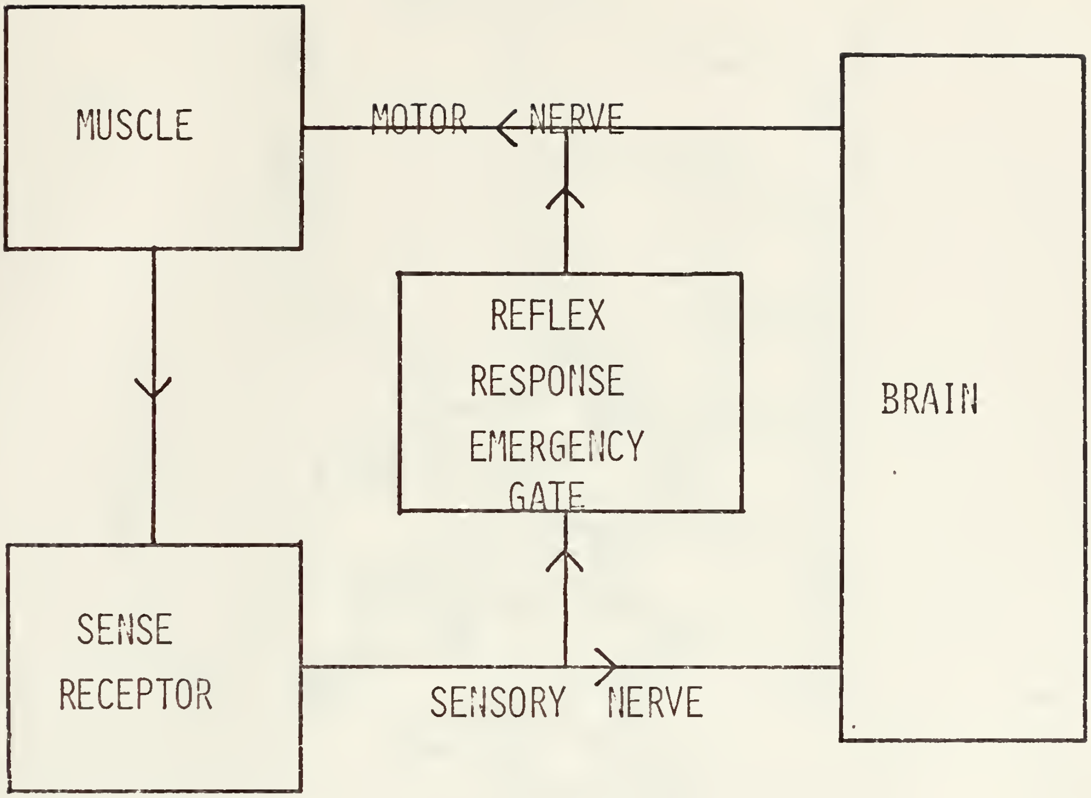


FIGURE 1

BLOCK DIAGRAM OF NERVOUS SYSTEM

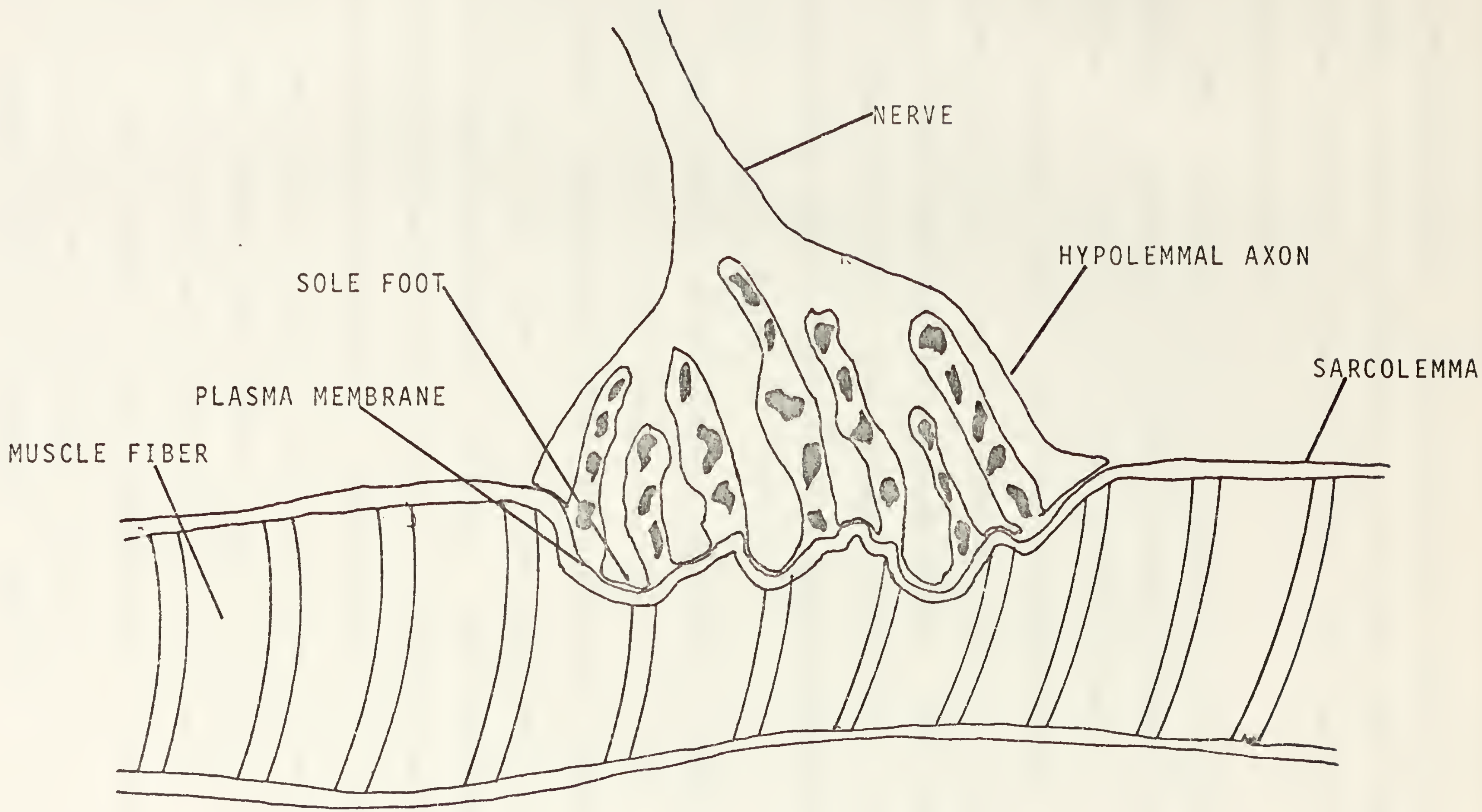


FIG 2

NEUROMUSCULAR JUNCTION

neuron or does not travel at all. This is called the all-or-nothing effect. The same principle applies in muscle fibers. That is, a stimulus to a muscle fiber causes an action potential to travel over the entire muscle fiber or fails to stimulate it at all.

When the action potential reaches the neuromuscular junction, vesicles of acetycholine are released from the end-plates into the synaptic cleft formed between the end-plate and the muscle fiber. The acetycholine increases the permeability of the muscle fiber membrane to sodium ions and is then destroyed by cholinesterase. The rapid influx of sodium ions raises the membrane potential to the threshold level and an action potential propagates in both directions along the muscle fiber.

Every muscle fiber contains thousands of myofibrils which in turn contain myosin and actin filaments lying side-by-side. The myofibrils are suspended in a matrix called sarcoplasm, which also contains the sarcoplasmic reticulum, an extensive endoplasmic reticulum. The sarcoplasmic reticulum system is composed of two distinct and separate types of tubules called the transverse or "T" tubules and the longitudinal tubules. When an action potential spreads over the muscle fiber membrane, the "T" tubules transmit electrical currents to the interior of the muscle fiber. This flow of current causes calcium ions to be released into the myofibrils which initiates the contractile process for the myosin and actin filaments. Therefore, in effect, the

action potential causes a short pulse of calcium ions in the myofibril, and it is during this time that the contractile process is activated. At the termination of this pulse of calcium ions, the muscle immediately relaxes.

Normal muscular movement is characterized by smoothness of motion, steadiness, and precision. These characteristics are the result of spatial summation and temporal summation. Spatial summation or multiple motor unit summation adds or sums the contraction of many motor units to make a strong and concerted muscle movement. Where as, temporal summation or wave summation is the summation of successive contractions of the same motor unit. However, it is rare for either multiple motor unit summation to occur separately. Instead special neurogenic mechanisms in the spinal cord control both the impulse rate and the number of motor units firing.

As the action potential passes along a muscle fiber, a small portion of the electrical current spreads away from the muscle as far as the skin. If many muscle fibers contract simultaneously, the sum of the electrical potentials at the skin is very great as shown in Figure 3.

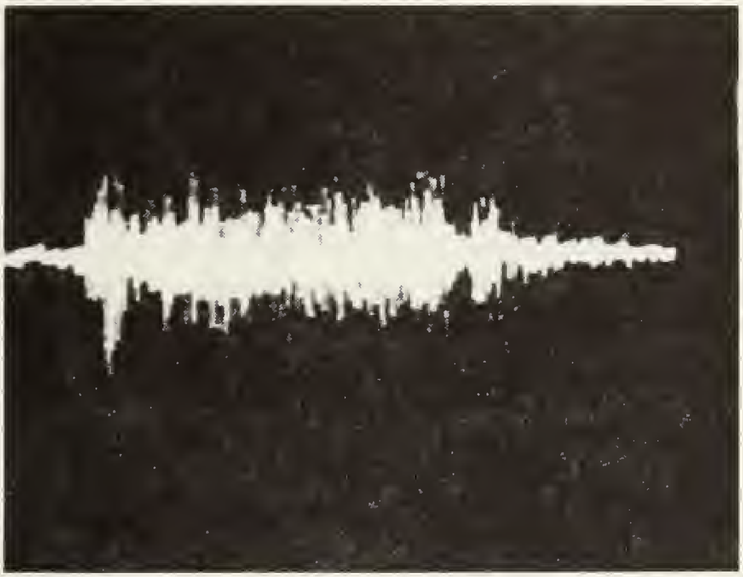


FIGURE 3

MYOELECTRIC SIGNAL

B. ELECTRODES

An electrode is an interface between the conducting tissue and the lead wires for the conversion of ionic currents in the conducting tissue to electron currents in the wires and conversely. There are three types of reversible electrodes (Ref. 4); (1) a metal in contact with a solution containing its ions; (2) a metal in contact with one of its insoluble salts immersed in a solution containing the ion which combines with the metal to form the insoluble salt; (3) a noble metal in contact with a solution containing a substance in two valence states. Reversible electrodes could then be made from many different metals including copper, zinc, aluminum, gold, platinum, and silver. The choice of an electrode requires consideration of such factors as degree of skin irritation, mechanical properties, toxicity, and electrochemical reversibility. For example, zinc is toxic to humans. Silver is one of the most widely used electrodes for biological applications.

A silver electrode is a type 2 reversible electrode, or an electrode of the second kind, and therefore must be plated prior to use. The result is a silver-silver chloride electrode. The reaction that takes place during plating and also during use is:

$$Cl^- + Ag \text{ (from electrode)} \rightleftharpoons AgCl + e^-$$

For current to flow between the tissue and the metallic circuit, the above reaction, which is reversible, takes place at the electrode-tissue interface. Contact between

the electrode and the skin is achieved by using electrode paste consisting of sodium chloride in a gelatinous matrix.

Experimentation has been conducted to find suitable replacements for the standard paste-type electrodes presently used (Refs. 1 and 9). Stainless-steel, anodic tantalum oxide, and aluminum oxide were some of the electrodes tested. Since the skin-to-electrode impedances are relatively high without electrode paste, high impedance buffer amplifiers had to be incorporated directly within the electrode housing. The silver-silver chloride electrodes used in this thesis will be described in the next section.

III. FUNCTIONAL DESCRIPTION

A. ELECTRODE UNIT

Two silver-silver chloride electrodes, mounted directly over one of the muscles of the fore-arm, pick up the myoelectric waveform. This waveform (Figure 3) is amplified by a differential amplifier (Figure 4) from approximately one millivolt at the electrodes to approximately 0.35 volts at the output of the differential amplifier. A silver-silver chloride loop, at ground potential, surrounds the two electrodes to provide noise suppression and isolation for the unit (Figure 5). The differential amplifier utilized two Burr Brown 3521 operational amplifiers in the configuration indicated in schematic 1, yielding a gain of 350 and a common mode rejection ratio of 70 dB. The electrodes used are Beckman miniature skin electrodes. Electrode paste is used between the skin and the electrode as a conducting medium.

The waveform is further amplified using a Tektronix 3A9 differential amplifier and sent on to the filter circuit. Figure 6 shows a myoelectric waveform using only two Beckman electrodes and the Tektronix 3A9. Figure 7 is the same waveform using the electrode amplifier unit and the 3A9. The signal to noise ratio has been greatly increased bringing the signal well out of the noise. This is the result of amplifying the signal close to the source to eliminate pick-up of manmade noise such as electrical power sources.

Figure 7 is a biphasic, compressed signal made up of responses from many motor units over a four second interval. The first electrode picks up the action potential as say a positive going spike followed by the second electrode picking up the same signal a short time later but with opposite polarity since the two electrodes are of opposite polarity, giving the biphasic effect. The compression is caused by recording the relatively short time duration signals over a long period of time to get the signals from many motor units.

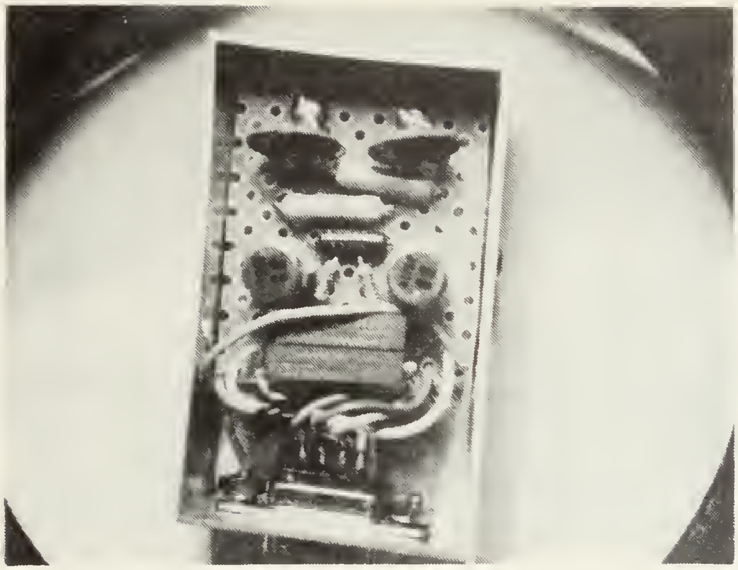
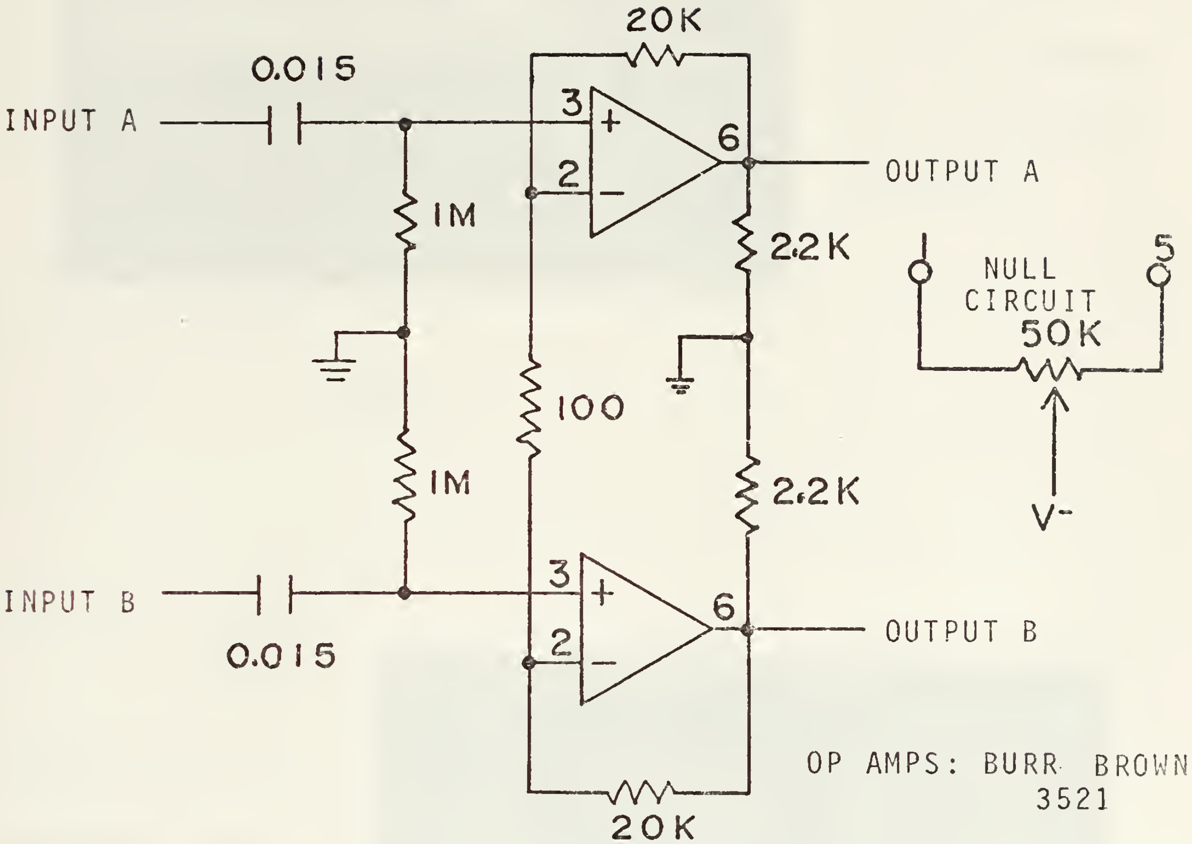


FIGURE 4

PIGGYBACK DIFFERENTIAL AMPLIFIER

Electrode unit showing the two Beckman electrodes surrounded by the silver-silver chloride grounding loop

FIGURE 5

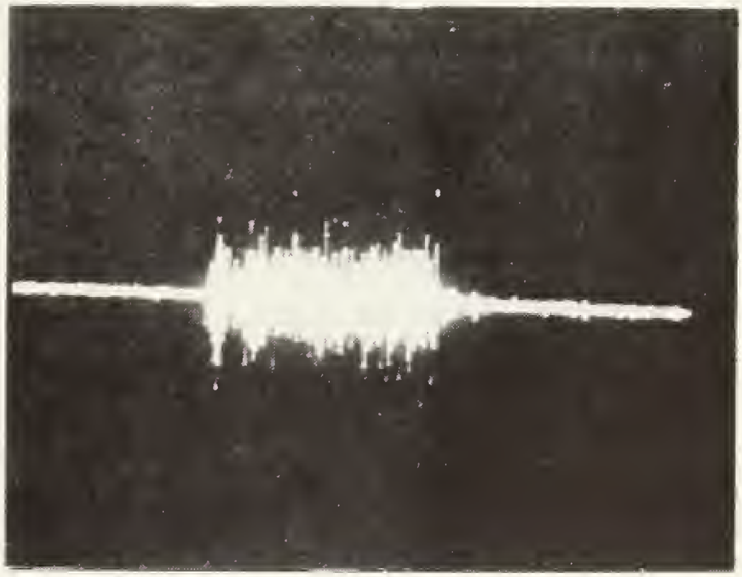


SCHEMATIC I

DIFFERENTIAL AMPLIFIER

Myoelectric waveform using two Beckman electrodes and the Tektronix 3A9 differential amplifier.

FIGURE 6



Myoelectric waveform using the new electrode unit with piggyback amplifier and the 3A9.

FIGURE 7

B. FILTER SECTION

Only the magnitude variation or envelope of the signal is desired so the signal is passed through a half-wave, capacitor-filtered rectifier or peak detector circuit, and then into an FET source follower which provides a low impedance input to the filter. Several filter designs were built and tested, and the most successful was found to be an active, fourth order Butterworth filter which was implemented in the final design. The filter is a low pass, four pole design with the gain down 3 dB at a frequency of 10 Hz; the low frequency gain is 8.2 dB.

C. MATRIXING NETWORK

The matrixing circuit provides the desired relationship between pitch and roll by allowing the proper signal to get through while at the same time cancelling out any unwanted signals. With the electrodes attached to each of the four muscles (Figures 23 and 24), any movement in either pitch or roll will produce a signal in at least two of the four muscles involved. For example, to produce left roll both flexor muscles of the fore-arm must be used, but one of the flexors would be used in a pitch up motion and the other would be used in a pitch down motion.

Referring to schematic 2, the two signals for left roll enter the FCU and FCR inputs of the matrixing network with the same polarity. The FCR signal is inverted in amplifier I and then back again in amplifier IV to mix with the FCU signal which is only inverted once in amplifier VI. Since

the signals are of opposite polarity and very nearly equal in magnitude they are cancelled resulting in no output from the pitch terminal. The FCU and FCR signals are also added prior to amplifier III without either one being inverted, which gives the desired output at the roll terminal.

IV. EXPERIMENTAL RESULTS

A. ELECTRODE UNIT

Some of the many factors which must be considered in the design of electrodes and the selection of amplifiers for biomedical applications are: stability, dc offset potential, electrode noise, and outside interference. Assuming a typical myoelectric signal of 0.001 and a maximum interference of 1 percent of the desired signal, the interference entering the system must be kept below 10 microvolts. Since independent signals from each of the four muscles are desired, interference from other muscles is a major problem. The other major problem is interference caused by the presence of currents in power lines and other electrical devices.

Earlier experiments (Ref. 2) relied on a matrix network to cancel out unwanted signals from other muscles, but it could not cancel out signals from other muscles feeding over into adjacent electrodes. To overcome this problem, several different electrode configurations were designed and tested. One promising design is shown in Figure 8. It is composed if an inner coil and an outer ring both made of silver wire with a silver-chloride coating. It is designed to pick up only potential differences between the inner and outer electrodes or signals only from the muscle directly beneath the electrode. The electrode appeared to function quite well but two problems developed. The signal from the electrode

contained a dc drift, and the electrode paste continually smeared between the two electrodes shorting out the signal.

The two greatest sources of interference are the power frequency electric and magnetic fields emanating from many sources such as lights, wiring, outlets, and other equipment. The changing magnetic field produced by an alternating current will induce in any nearby conductive loop an electromotive force which results in an ac potential. An alternating potential from the power cords of equipment which is turned off but still plugged in produces a changing electric field which will give rise to interference by causing ac currents to flow to ground through the system. These currents flowing through the tissue and electrode impedences produce ac potentials which interfere with the myoelectric signals. Figure 9 shows how the interference, capacitively coupled into unshielded leads and body tissues, effects the signal.

To eliminate the magnetic interference, the leads should be kept as short as possible and should be twisted. To eliminate the electric interference, the electrode contact must be good, all leads and other components must be equal or balanced, and the ground placement must be such that the potentials at each electrode are equal (Ref. 8). By using a differential preamplifier as close as possible to each set of electrodes, the leads are kept short and electrical interference is minimized. The final design (Figures 10-12) utilized a grounded loop electrode surrounding the active

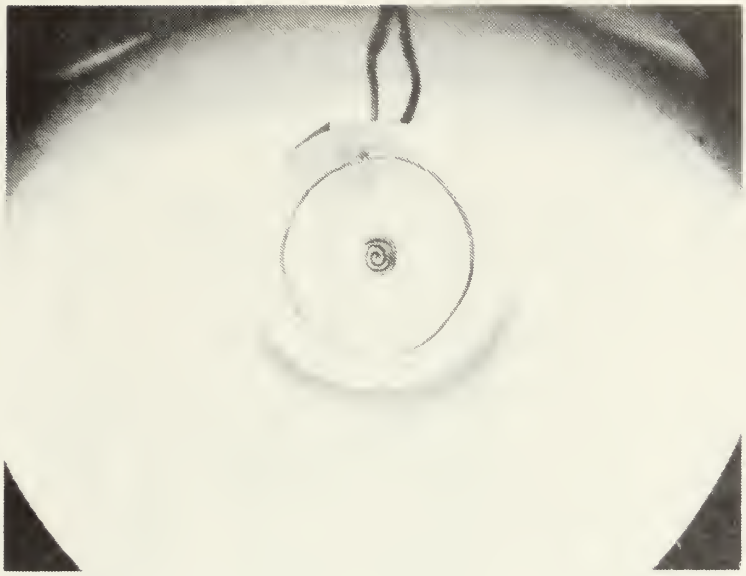


FIGURE 8

CONCENTRIC ELECTRODE

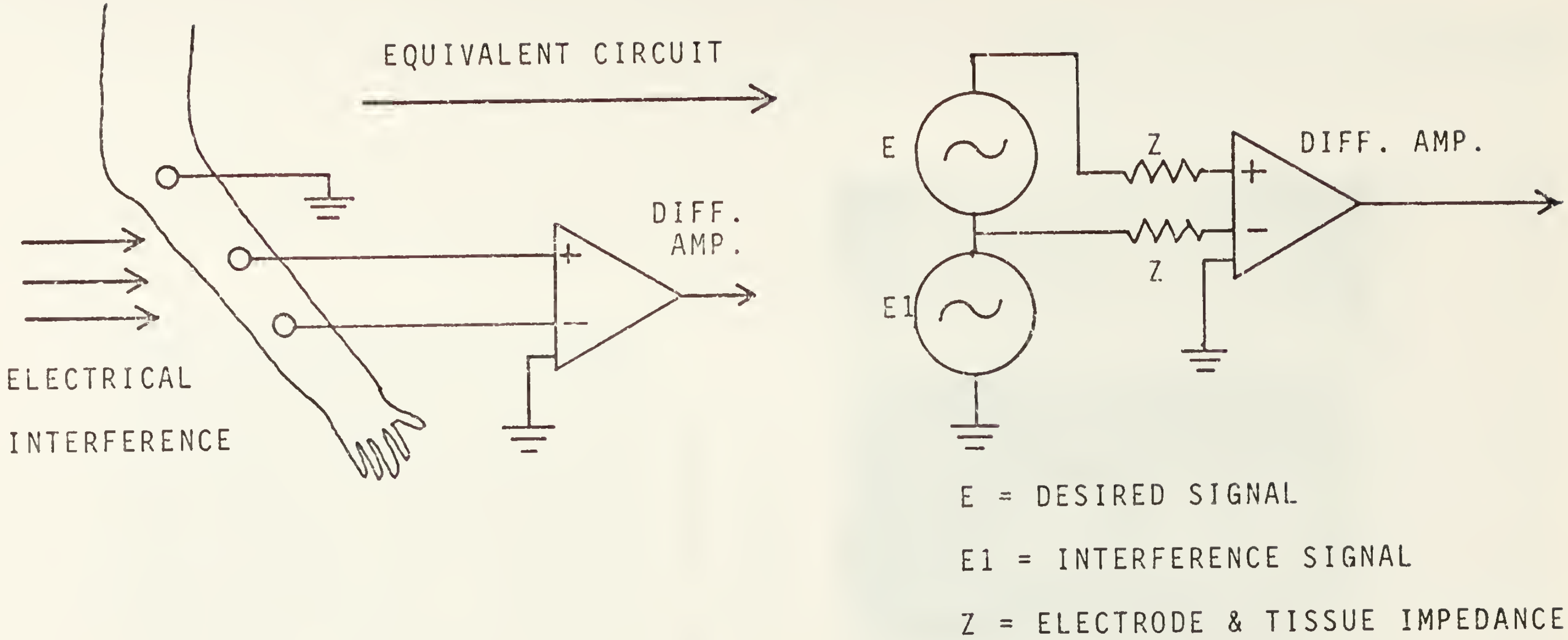


FIGURE 9

OUTSIDE INTERFERENCE

FIGURE 10

ELECTRODE UNIT

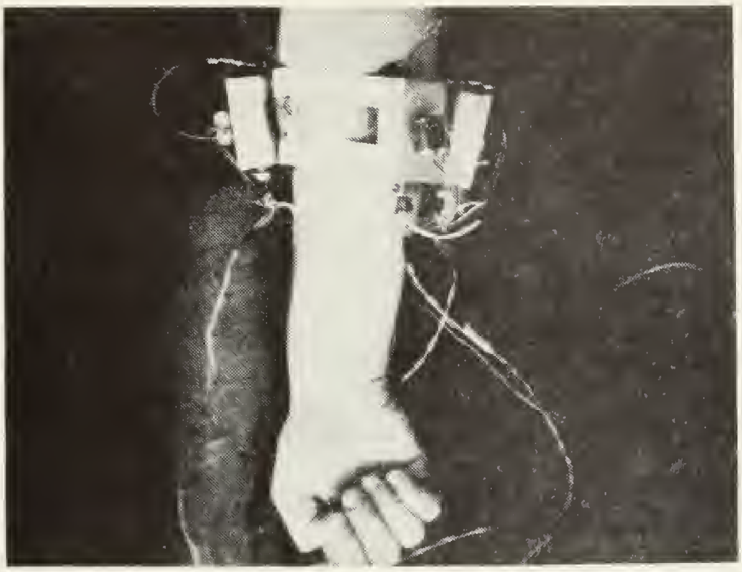


FIGURE 11

Figure 11 and 12 show the electrode units with piggyback amplifiers attached to the subjects arm.

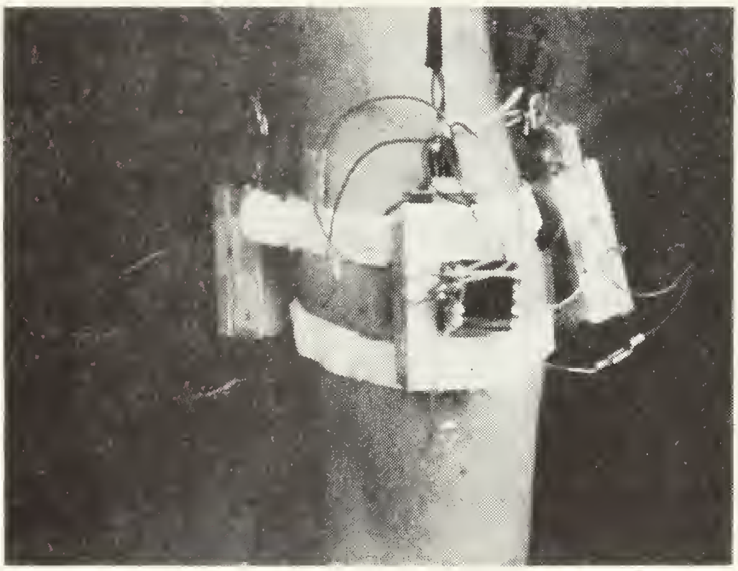


FIGURE 12

electrodes to eliminate pickup from other muscles and a differential amplifier mounted on top of the electrodes.

Results using this electrode-amplifier configuration were very good. Figures 5 and 6 show a large increase in signal to noise ratio with the new electrode unit compared with the standard two electrode configuration. Figures 13-16 show the large difference in amplitude in a signal from an adjacent muscle and a signal from the desired muscle. This difference is due to the isolation of the electrodes in the unit provided by the ground ring.

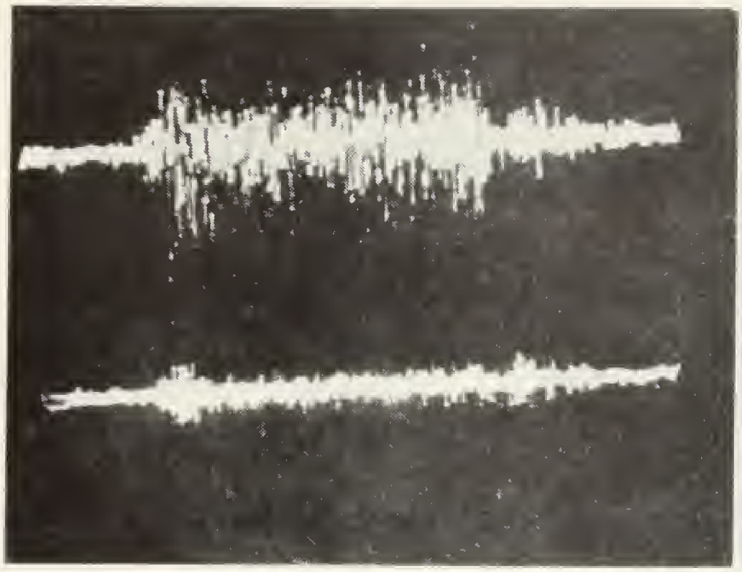
Since the signal picked up at the surface of the skin is very small, the noise generated in the preamp had to be minimized. Low noise, low frequency, operational amplifiers with very small input offset currents were used.

B. FILTER SECTION

The next step was to design a detector and filter to smooth and pass only the magnitude variations or envelope of the myoelectric signal. A frequency analysis of the myoelectric waveform showed a spectrum ranging from several Hz to over 100 Hz with maximum power in the 40 to 50 Hz range.

The linear detector circuit utilized a germanium diode to take advantage of its low threshold or cut-in voltage of 0.2 volts. The output of the detector (Figure 17), the positive or negative envelope of the myoelectric responses, is passed through a passive RC filter and then an active filter to obtain a smooth representation of the magnitude

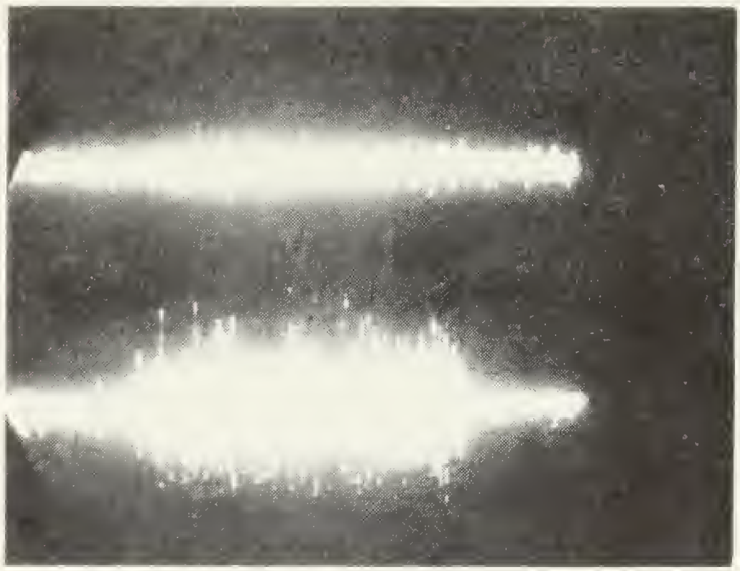
of the envelope. Figures 18 and 18A show the output of the detector circuit compared with the output of the final filter, and Figures 19-22 show the input signal from the various muscles and the signals as they appear at the output of the active filter. At the same time, however, the filter must react quickly enough to changes in amplitude to allow for positive control of the aircraft. Several filters were built and tested, and an active, four pole, low pass Butterworth filter proved to be the most effective for the final stage. This filter has a 10 Hz 3dB frequency and a low frequency voltage gain of 2.5. An FET used in a source follower configuration acts as a buffer between the detector circuit and the active filter. It provides the low impedance required by the filter, and is biased to provide a zero dc level with direct coupling to the filter.



0.5 sec/cm 1 volt/cm

Figure 13

Figures 13-16 show the isolation between the electrode units of the four muscles when one muscle is contracted.



0.5 sec/cm 1 volt/cm

FIGURE 14

Extensor Carpi
Radialis

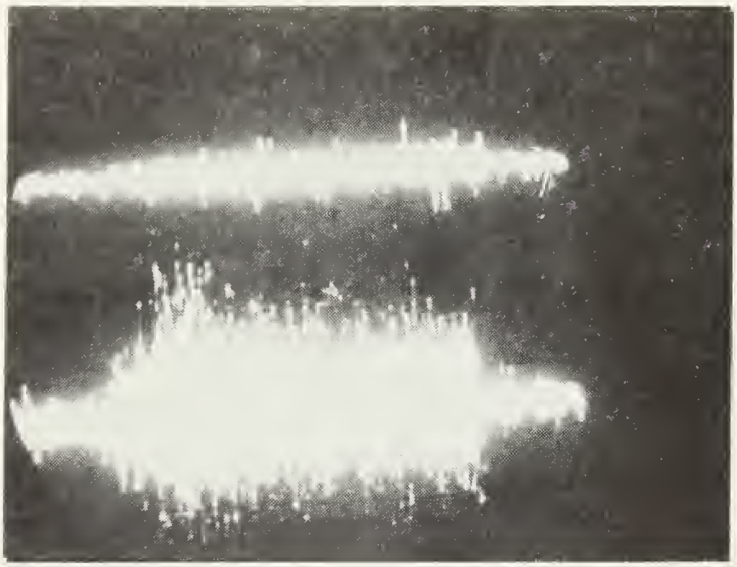
Extensor Carpi
Ulnaris

0.5 sec/cm 1 volt/cm

FIGURE 15

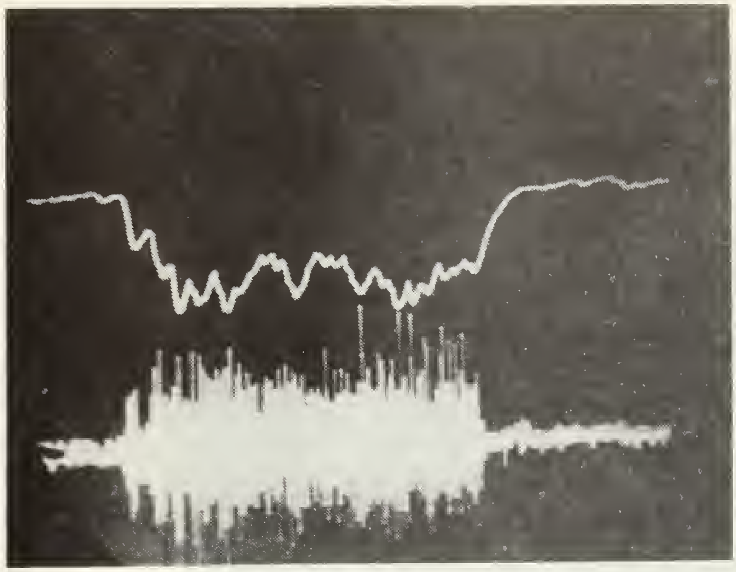
Flexor Carpi
Ulnaris

Extensor Carpi
Radialis



0.5 sec/cm 1 volt/cm

FIGURE 16



The top trace shows the output from the detector circuit compared with the input on the bottom trace.

FIGURE 17

The bottom trace shows the output from the detector circuit compared with the output from the active filter on the top trace.

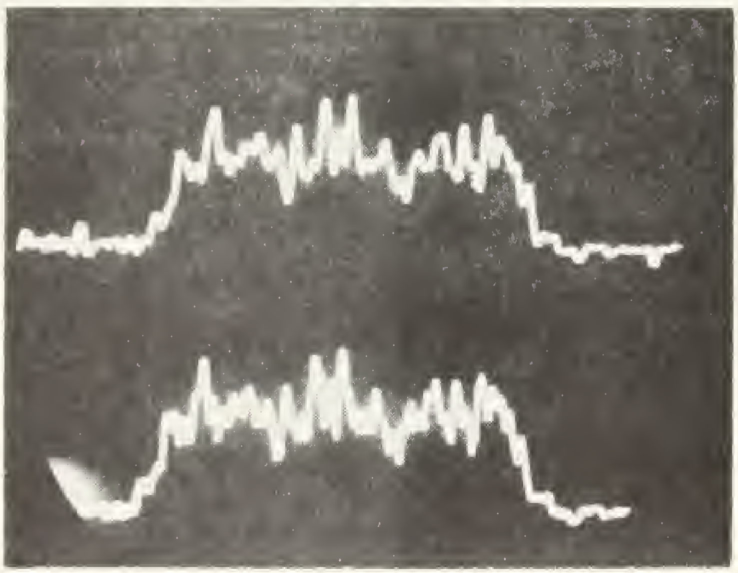


FIGURE 18

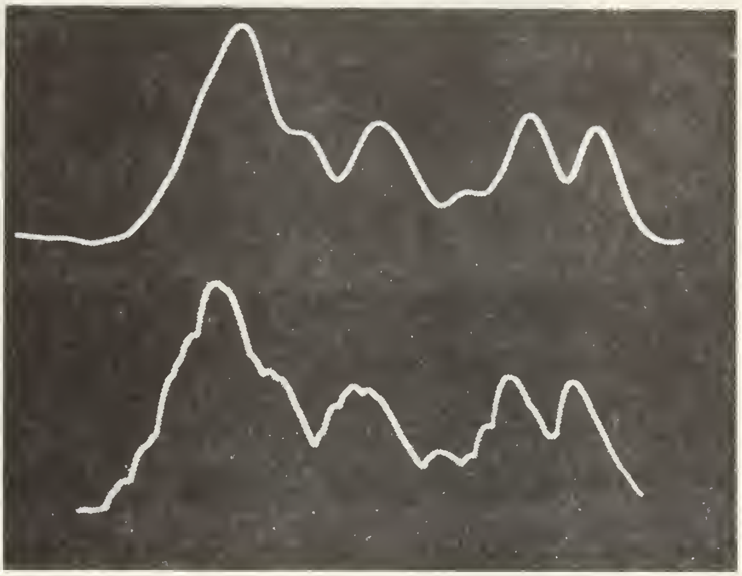
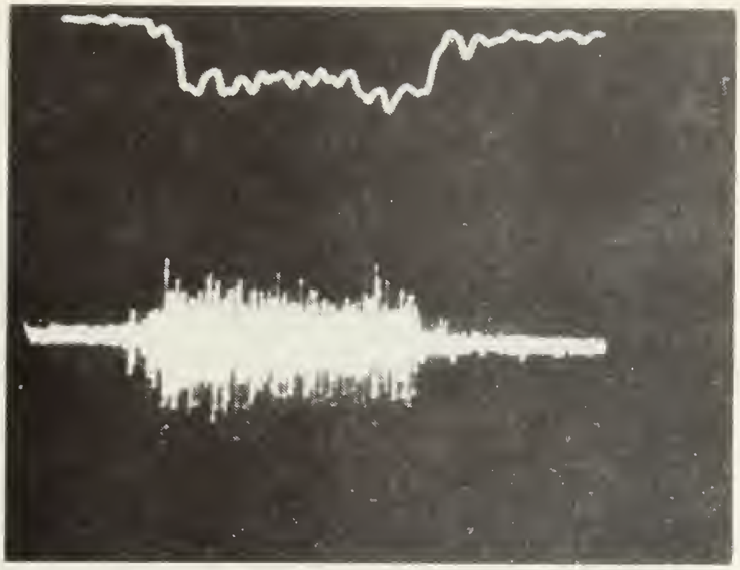


FIGURE 18A

In this expanded view of Figure 18, the filtering accomplished by the active filter is demonstrated. The detector circuit output is shown on the bottom trace and the output from the active filter on the top trace. The filtered output preserves the required rise time while removing higher frequencies.

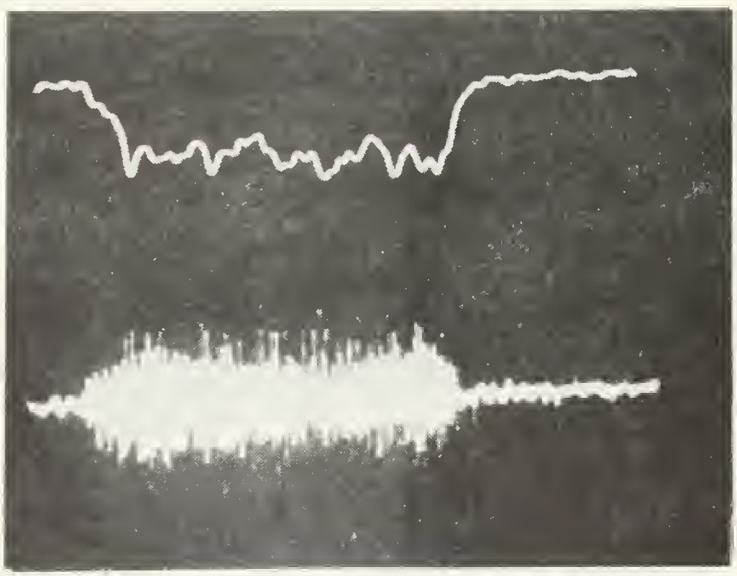


Flexor Carpi
Ulnaris

0.5 sec/cm 1 volt/cm

FIGURE 19

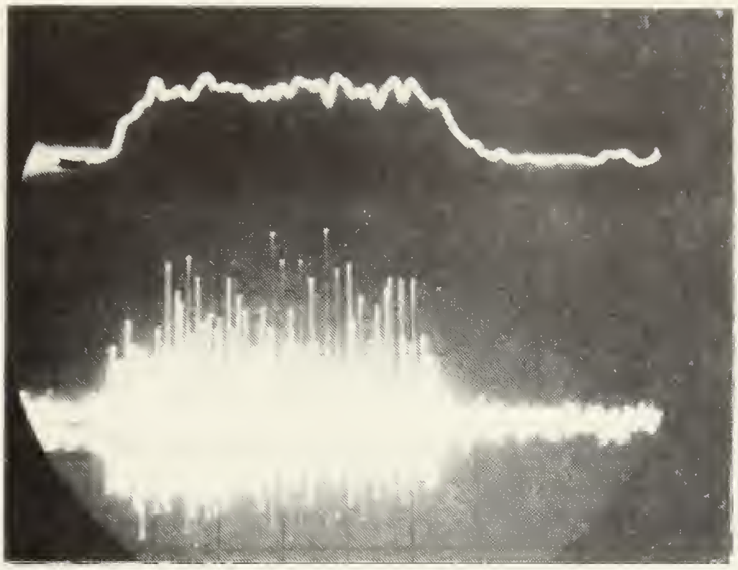
Figures 19-22 show the signal after the filter on the top trace and the input to the detector on the bottom trace.



Flexor Carpi
Radialis

0.5 sec/cm 1 volt/cm

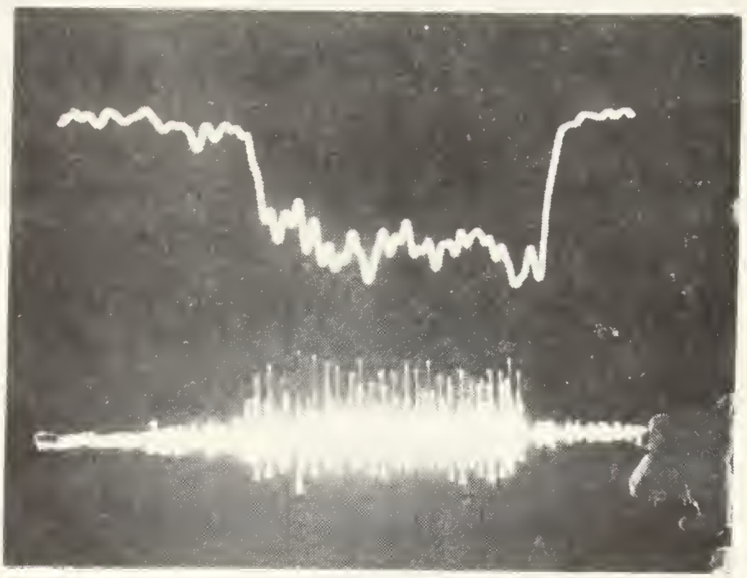
FIGURE 20



Extensor Carpi
Radialis

0.5 sec/cm 1 volt/cm

FIGURE 21



Extensor Carpi
Ulnaris

0.5 sec/cm 1 volt/cm

FIGURE 22

C. MATRIXING NETWORK

Two of the basic signals required for control of an aircraft are for pitch and roll. Since present-day practice uses fore-arm muscles in controlling pitch and roll, and using any other practice would require relearning, the fore-arm muscles were used in this study. Figures 23 and 24 show the four large muscles of the fore-arm considered to be the "prime movers" of the two directions in both pitch and roll. Independently, each of these muscles produces only diagonal movement of the hand, and since normal movement from child-hood uses combinations of these muscles, a matrixing net-work is necessary to produce pure right roll, left roll, pitch up or pitch down without retraining the man to learn new hand movements. The four prime movers and their asso-ciated movements are:

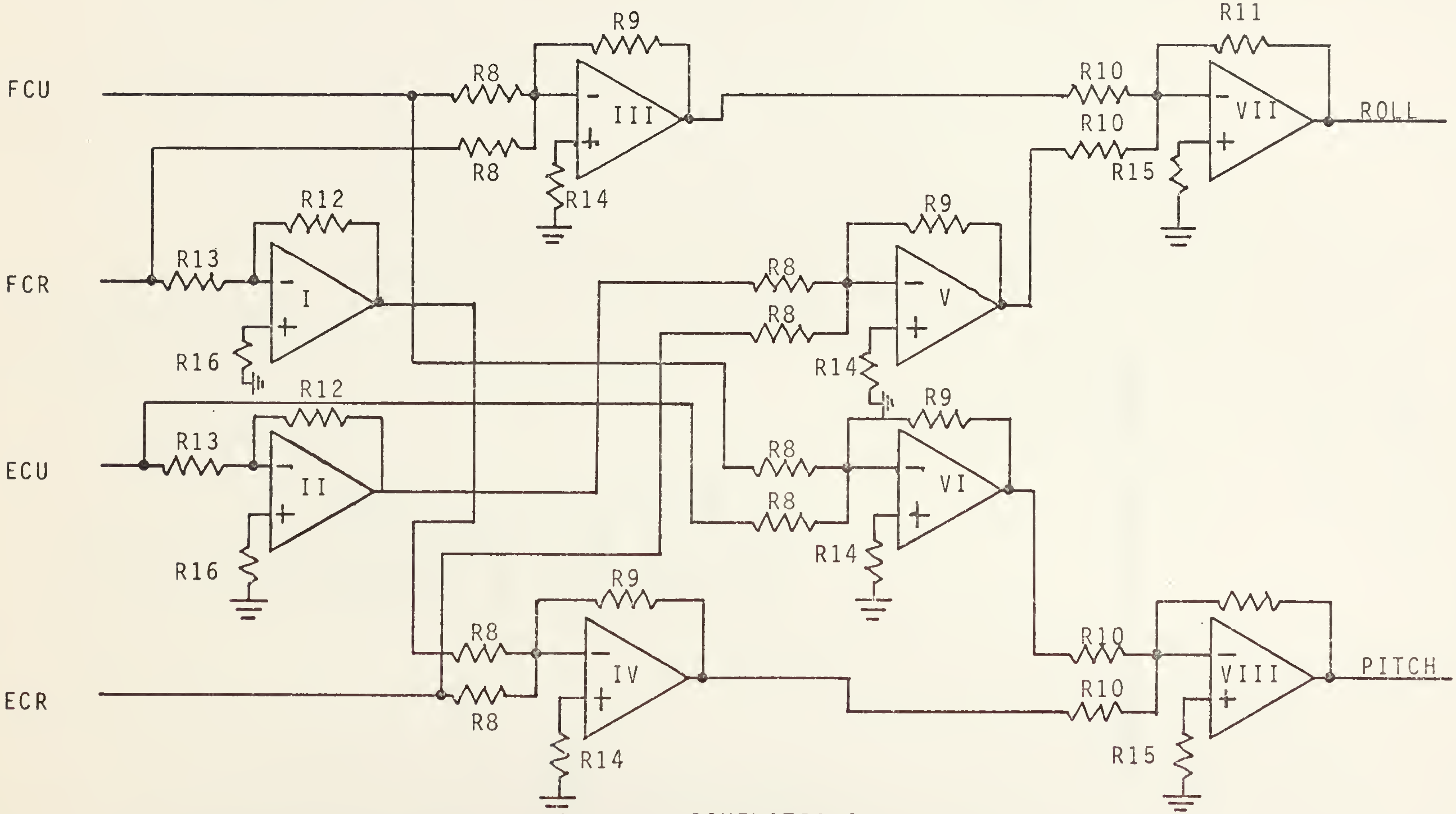
flexor carpi radialis (FCR)	flexion and abduction
flexor carpi ulnaris (FCU)	flexion and adduction
extensor carpi radialis (ECR)	extension and abduction
extensor carpi ulnaris (ECU)	extension and adduction

As in Ref. 2, this study translates the following movements into pitch and roll:

flexion	left roll
extension	right roll
abduction	pitch up
adduction	pitch down

To get the signals desired for pitch and roll, the small signals from opposing pairs of muscles must be cancelled out and the desired signals delivered to the correct output. The matrixing scheme is similar to that used in Ref. 2; however, by using operational amplifiers in the summing circuits, a much more clean cut separation of the signals was achieved. The final network (Schematic 2) utilizes Fairchild uA741 operational amplifiers as inverters and summing amplifiers. The total gain in the matrixing network is 11.6 dB.

Figures 25-28 show the roll signal on the top trace and the pitch signal on the bottom trace. Left roll produces an upward shift in the roll signal while the pitch signal maintains a relatively constant level. Right roll produces a downward shift in the roll signal. Pitch up produces a downward shift in the pitch signal. And, pitch down produces an upward shift in the pitch signal.



SCHEMATIC 2

MATRIXING NETWORK

R8=2.21K

R9=6.42K

R10=15K

R11=15K

R12=10K

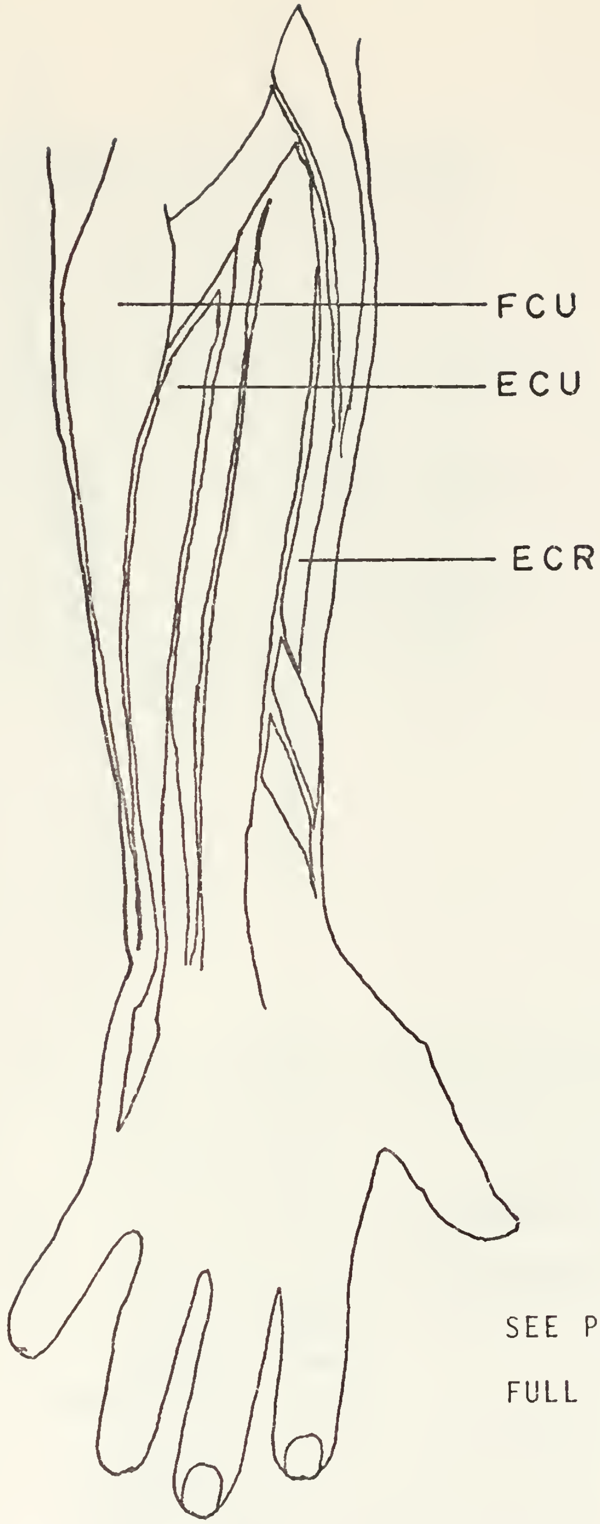
R13=10K

R14=1.62K

R15=7.5K

R16=5K

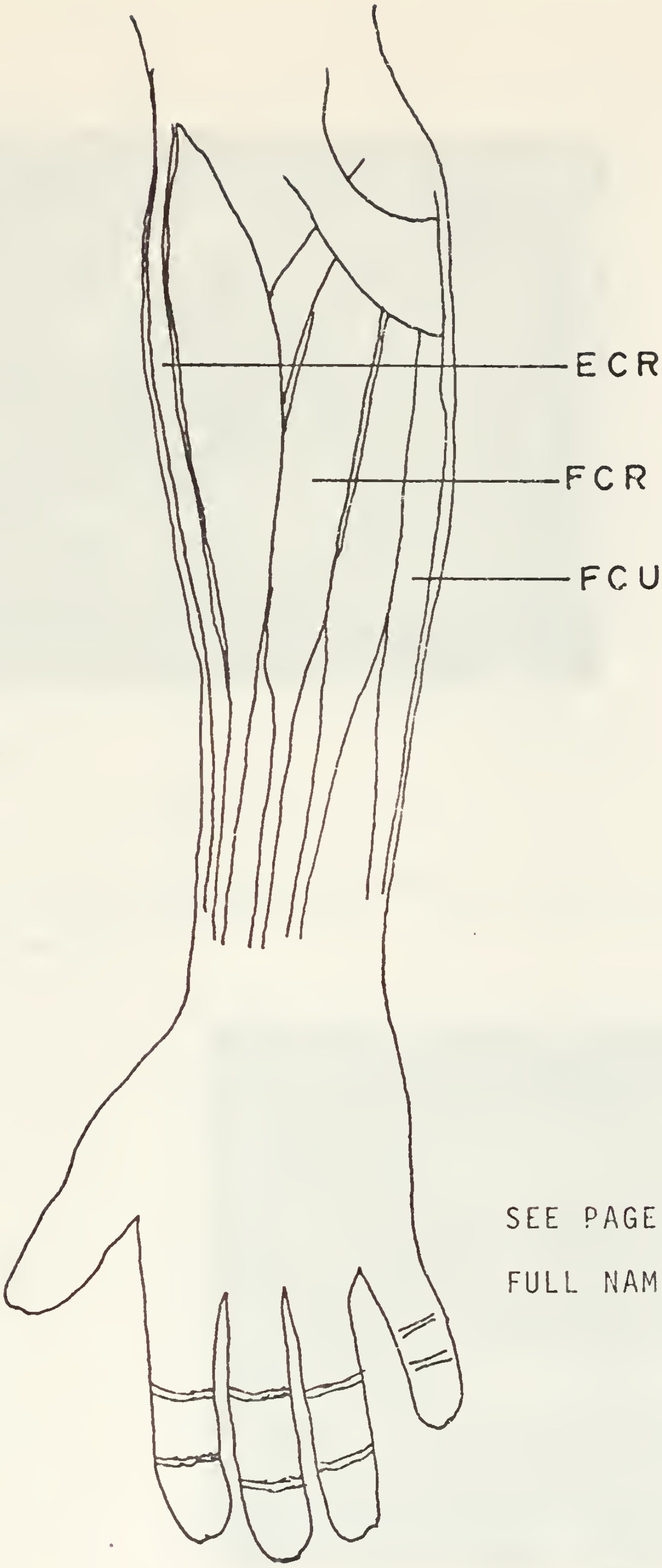
SCHEMATIC 2 COMPONENT VALUES



SEE PAGE 37 FOR
FULL NAMES OF MUSCLES.

FIGURE 23

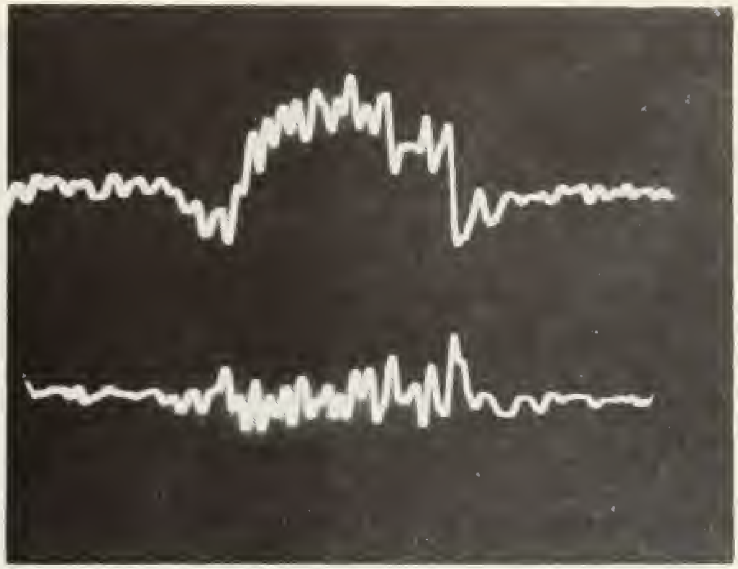
PRIME MOVERS



SEE PAGE 37 FOR
FULL NAMES OF MUSCLES.

FIGURE 24

PRIME MOVERS



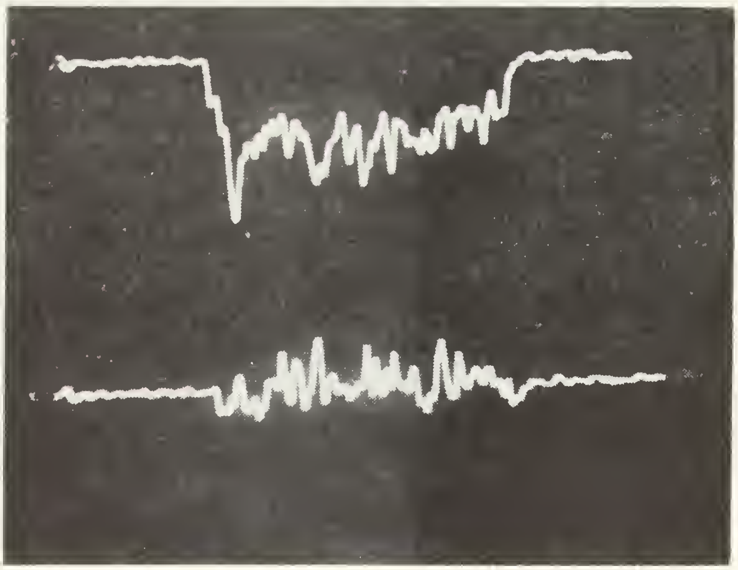
LEFT ROLL

0.5 sec/cm 1 volt/cm

FIGURE 25

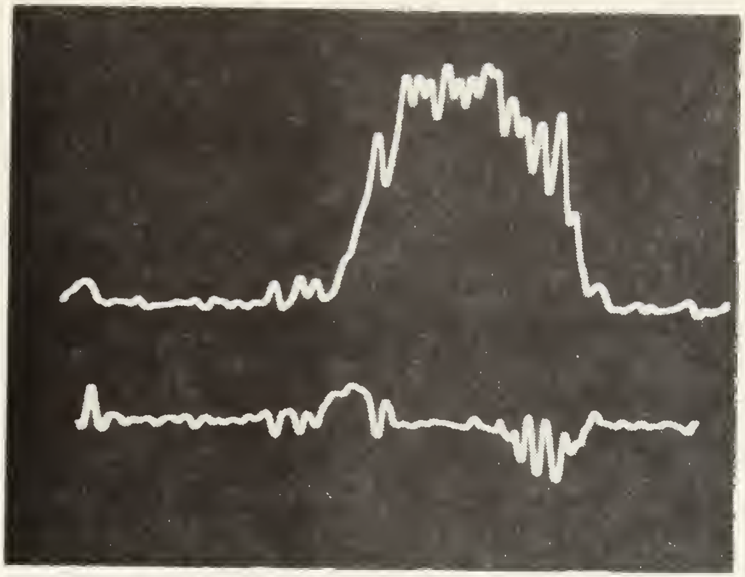
Figures 25-28 show roll response on the top trace and pitch response on the bottom trace. Note lack of dc response in the pitch responses.

RIGHT ROLL



0.5 sec/cm 1 volt/cm

FIGURE 26

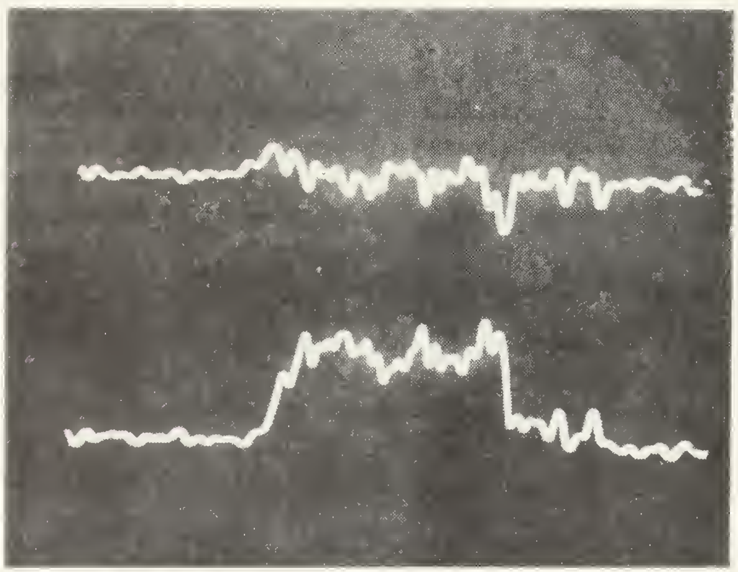


PITCH UP

0.5 sec/cm 1 volt/cm

FIGURE 27

PITCH DOWN



0.5 sec/cm 1 volt/cm

FIGURE 28

V. CONCLUSION

A. ELECTRODE UNIT

The electrode units performed very well in rejection of signals from adjacent muscles and elimination of outside interference. Placement is critical since they are designed to pick up signals only from muscles directly beneath them, and a shift in position could render them inoperative or in error.

The electrode unit could be improved by using an open frame to hold the outer ground wire with the electrodes suspended in the middle. This would eliminate grounding of the electrodes by shorting due to electrode paste smearing or perspiration.

B. INTERFACING NETWORK

The complete interfacing network was tested repeatedly and proved to be quite satisfactory. Figures 25-28 show that individual signals for pitch and roll can be obtained for interfacing to an aircraft system. An electrical interface has the advantage of allowing the addition of other circuits, for example, to compensate for overshoot in arriving at a pitch signal. With the present state of the art techniques, electronic pilot to aircraft interfacing is considered feasible and will probably be realized in the near future.

C. APPLICATIONS

This technique of man-machine interfacing has many practical applications other than aircraft control. Ever since 1945, research has been conducted in limb presthetics especially to meet the needs of World War II casualties. Now after Viet Nam, there are many more who are in need of prosthetics which are more sophisticated yet easier to use.

Myoelectric control of electric powered prostheses has been applied with some success at several institutions (Ref. 3). A simple myoelectrically controlled hand prosthesis developed in the Northwestern University Prosthetic Research Laboratory employs stainless-steel electrodes, permanently embedded in the limb to sense the myoelectric potentials resulting from nearby muscle contraction. The signals are amplified, detected, smoothed, added, and used to drive a motor which opens and closes a hand providing one degree of freedom. The wrist extensor and flexor muscles are used to open and close the hand since the natural conditioning provides for faster subconscious operation after only a few months of practice.

An Italian scheme developed by Schmidl uses two amplitude levels from the same muscle, one to close the hand and the other to open the hand. This type of control requires operant conditioning.

A pattern recognition scheme for myoelectric control was devised by workers at Philco. This concept weighs and analyzes ten muscle cites in the shoulder area to determine what action should be taken by the artificial limb.

The techniques developed in this thesis would provide a wider range of possibilities for controlling several movements at the same time than the first method described above, and would not be as complicated as the last method.

Using a grounded loop along with the embedded stainless-steel electrodes would probably provide myoelectric signals from individual muscles without interference from adjacent muscles. When connected to the circuit setup described in this thesis, four possible signals, two positive and two negative, would be provided, with amplitude and polarity controlled by the signals from a set of four muscles. This type of circuit setup could be extended to process signals from a larger set of muscles to provide a more sophisticated type of prosthetic control.

BIBLIOGRAPHY

1. Bergy, G. E., Squires, R. D., and Sipple, W. C., "Electrocardiogram Recording With Pasteless Electrodes," IEEE Transactions On Bio-Medical Engineering, v. 18, no. 3, p. 206-210, May 1971.

2. Boehmer, C. E., A Biophysical Analysis of Aircraft Control Sticks, M.S. Thesis, Naval Postgraduate School, 1973.

3. Childress, D.S., "Powered Limb Prostheses: Their Clinical Significance," IEEE Transactions on Bio-Medical Engineering, v. 20, no. 3, p. 200-207, May 1973.

4. Cooper, R., Osselton, J.W., and Shaw, J.C., EEG Technology, Butterworth, 1971.

5. Enstinger, J.E., A Prototype Fly-By-Wire Flight Control System, Air Force Flight Dynamics Laboratory Technical Report 69-9, August 1969.

6. Guyton, A. C., Textbook of Medical Physiology, Saunders Co., 1971.

7. Hood, "J" "V", Equipment Control By Surface Electromyography, M.S. Thesis, Naval Postgraduate School, 1972.

8. Huhta, J.C. and Webster, J.G., "60-Hz Interference in Electrocardiography," IEEE Transactions On Bio-Medical Engineering, v. 20, no. 2, p. 91-101, March, 1973.

9. Lagow, C.H., Sladek, K.J., and Richardson, P.C., "Anodic Insulated Tantalum Oxide Electrocardiograph Electrodes," IEEE Transactions on Bio-Medical Engineering, v. 18, no. 2, p. 162-164, March 1971.

10. Millman, J. and Halkias, C.C., Integrated Electronics: Analog and Digital Circuits and Systems, McGraw-Hill, 1972.

11. Plonsey R., Bioelectric Phenomena, McGraw-Hill, 1969.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Library, Code 0212 Naval Postgraduate School Monterey, California 93940	2
2.	Professor George Marmont, Code 52Ma Department of Electrical Engineering Naval Postgraduate School Monterey, California 93940	7
3.	Department Chairman, Code 52 Department of Electrical Engineering Naval Postgraduate School Monterey, California 93940	2
4.	LT Kenneth W. Morge, USN 3169 Ninole Dr. Marina, California 93933	1
5.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2

Thesis 160506
M82267 Morge
c.1 A new method of
interfacing pilot to
aircraft.